

CHAPTER 7

GLOVEBOX FILTRATION

7.1 INTRODUCTION

Gloveboxes are enclosures that enable operators in various industries (e.g., nuclear, biological, pharmaceutical, microelectronics) to use their hands to manipulate hazardous materials through gloves without exposure to the operator or subsequent release of the material to the environment. In the nuclear industry, gloveboxes provide primary containment for radioactive material handling and process protection and are used to handle a diverse range of chemical, oxygen-sensitive, pyrophoric, hazardous, and nuclear materials. Secondary containment is provided by the building where the gloveboxes are located.

Ventilation is the heart of the glovebox system. Nuclear materials requiring handling inside a glovebox usually present little or no penetrating radiation hazard, but emit radioactive particles that could be dangerous if inhaled. Gloveboxes prevent operators from inhaling these radioactive particles as they work with various nuclear

materials to help provide a clean, controlled, safe working environment. For glovebox ventilation to be effective, however, proper design pressures and flow criteria must be maintained. Glovebox pressures range from mostly negative (for containment) to positive pressure environments (for process protection). Failure to maintain correct operational pressures or to follow established operational procedures could render a glovebox ineffective and unsafe.

This chapter discusses filtration of air or other gases associated with glovebox ventilation. To understand the importance of glovebox filtration, a clear understanding of glovebox characteristics and functions is necessary.

7.1.1 GLOVEBOX DESCRIPTIONS

A glovebox (**FIGURE 7.1**) is a windowed, airtight (sometimes gas-tight) enclosure that may be capable of positive or negative internal pressure and is equipped with one or more flexible gloves for manipulation of materials and performance of

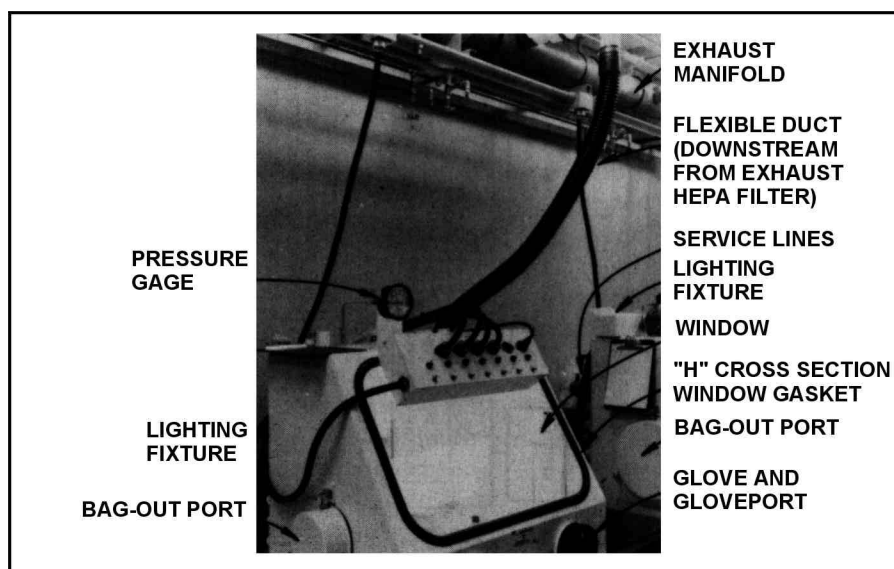


Figure 7.1 – Typical glove box showing major features

²⁸ which was written by government employees and vendors who work with, manufacture, and design gloveboxes. This document contains very useful information on subjects from glovebox need to quality assurance acceptance programs.

There are still manufacturers who produce “research-type” gloveboxes in the United States today. These boxes can be used by some U.S. Department of Energy (DOE) facilities, but it is not advisable to use these boxes for nuclear activities, as most are not equipped with a method to safely change the High-Efficiency Particulate Air (HEPA) filters and may not meet the provisions of this chapter. It should also be noted that the HEPA filters used on some of these gloveboxes do not meet the requirements provided in [Chapter 2](#) or ASME AG-1.²⁹

Ongoing development of gloveboxes for use by the nuclear industry has resulted in many changes

through the years. Gloveboxes have evolved from the somewhat standard sizes that are still used to larger custom systems containing all of the process-related equipment. The larger gloveboxes cited in this document have some unique characteristics. Some are as large as 150 ft long, 4 ft deep, and 15 ft tall. Their ventilation design includes side-access filter housings (see Chapter 4) instead of the designs described in this chapter. Other design philosophies give drive motors, equipment, and electrical devices external placement, thereby reducing maintenance, heat loading, size, and disposal costs. Seals are used to pass drives and electrical controls through the glovebox pressure boundary. In some cases, the design philosophy has been to size the glovebox for a specific process to minimize volume and service requirements. In all cases, ergonomics and containment are critical to performance of daily operations and routine maintenance.

Gloveboxes generally have several common characteristics. They are often no deeper than 26 in. (as far as most arms can reach—it is desirable to be able to reach most areas of a glovebox). If deeper space is needed, dual side-access may be selected. They contain one or more safety glass, laminated-glass, or polymer viewing windows located on at least one side, and glove ports (window-mounted or in the stainless steel shell) usually are available in multiples of two at various

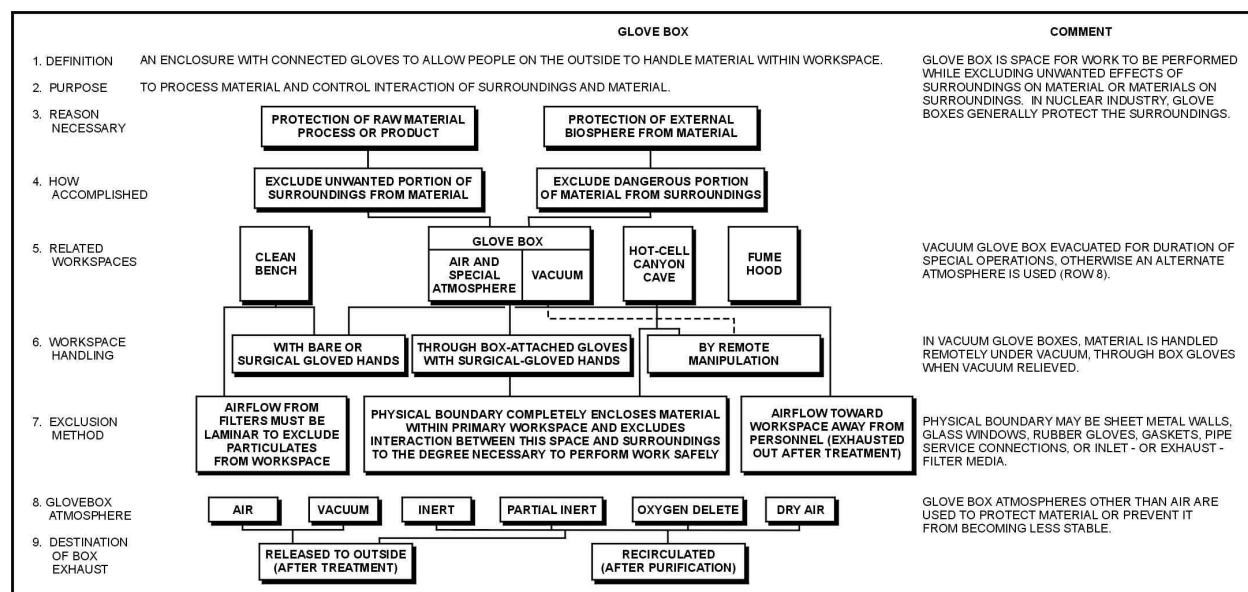


Figure 7.2 – Characteristics of gloveboxes

locations in the glovebox walls. Interior workspace is reserved for primary operating purposes on the box floor between the glove ports and within reach of a gloved hand. Remote handling capabilities, other than tool extensions for the gloved hand, are usually not provided. Gloveboxes are normally kept at a negative pressure of 0.3 to 0.5 in.wg relative to their surroundings. The maximum safe differential pressure between the interior and exterior of the box is usually less than 4 in.wg; greater differential pressure may damage or rupture a glove or window, causing subsequent loss of containment. Operators experience fatigue when pressures inside a glovebox are greater than 0.5 in.wg, and performance of intricate tasks becomes tedious. Material and HEPA filter transfers between glovebox interiors and exteriors are commonly made through a bagging port which, although time-consuming and user-dependent, is still the safest practical way of maintaining containment. New versions of this technology use a banding system (covered in Section 7.4). Other transfers related to "material" transfers use Rapid Transfer Ports (RTPs), which allow simple docking from glovebox to glovebox. This is a reliable method of maintaining containment as long as the seals are maintained and not damaged. It is important to note that transfers of powders can egress past the seals if exposed. Such powders should be contained in a secondary container and the seals protected during operations. Gloveboxes with RTPs are still equipped with bagging ports for filter changes and waste disposal.

HEPA filter installations must adapt to limitations and still provide reliable service. Hybrid glovebox-shielded cells, vacuum gloveboxes, room-high gloveboxes, glovebox "trains," etc., are often encountered, and all of these require reliable filter installations.

Special atmospheres such as inert gas and dry air are often used in gloveboxes for fire suppression and for oxygen-sensitive and/or moisture-sensitive materials and processes. Gas purification systems are commonly used in conjunction with inert environments to maintain environmental control. These units purify and dry the environment to prevent consumption of large volumes of inert gas and desiccant. It is important to protect these devices from contamination

because they constantly recirculate the volumes of the gloveboxes they serve.

7.1.2 IMPORTANCE OF GLOVEBOX VENTILATION AND FILTRATION

Operations conducted in gloveboxes often provide the elements for unstable conditions (e.g., fire and pressurization). A properly designed and operated glovebox ventilation system minimizes these instabilities and the possibility of an accidental release of airborne radioactive material. Room air is a safe glovebox environment for many applications. On the other hand, operations with pyrophoric materials such as plutonium, or the presence of reactive gases such as hydrogen, may require a special environment (e.g., low oxygen, inert gas, and moisture control).

For air-atmosphere boxes, ventilation at relatively low flow rates provides sufficient dilution of the limited combustible volatiles found in well-operated gloveboxes. The correct airflow volume, along with the proper location of supply and exhaust filters, minimizes the likelihood of fire while providing sufficient dilution to prevent the buildup of explosive gases (see Section 7.2.1). Good glovebox ventilation dictates that HEPA filters are operated at a designed airflow speed (100 fpm) and designed air volume (cfm). It is important to note that HEPA filters are tested and certified at this air velocity. As velocity increases, efficiency decreases.

Normal air changes through a glovebox remove some of the heat generated by equipment inside the box and help maintain reasonable working temperatures for the operator. However, this convective cooling may be insufficient to remove all of the process heat generated in the box, and auxiliary cooling or higher airflow volume may be required (Section 7.2.2). Most glovebox ventilation systems include some form of pressure relief (Section 7.2.6) and adequate pressure control to maintain proper pressure differentials between the glovebox and its surroundings (Section 7.2.5). If a glove should tear or accidentally come off, there should be an assured, sufficient ingress of air through the glove port to prevent egress of contamination until the port is closed (Section 7.2.4). This is an inherent safety feature if the glovebox ventilation is designed and operated properly. Pyrophoric operations, however, should

have appropriate safeguards to prevent air intake from starting a severe reaction.

Proper instrumentation should be provided to warn of inlet/exhaust filter blockage and loss of pressure/containment. Pressure gauge/transducer line filters (Section 7.2.5) should be used to protect this instrumentation.

HEPA filters have been used on gloveboxes to contain radioactive materials since the early days of the nuclear industry. History has shown that, as a rule, this has been adequate; however, submicron-sized particles of some materials can pass through HEPA filters. In such cases, it is critical to have knowledge of the material properties. Technology should be used to help understand the type of filters and efficiencies that can be used for a proper filtration system.

In short, the glovebox ventilation and filtration system must be capable of reliable performance to assure glovebox operators that they may safely operate the box without fear of exposure to airborne contamination to themselves, other facility personnel, and the environment.

7.2 DESIGN OF GLOVEBOX VENTILATION SYSTEMS

The principals of glovebox containment are very basic. Experience has shown that an airflow of 100 fpm through a breached (8-in. diameter) glove port will maintain containment. This is an inherent (defined as “real time, at the moment of failure”) safety feature that should be incorporated into the glovebox system. Most nuclear, biological, and pharmaceutical facilities in the United States are designed to provide this capability (within a range of 10 percent). It is important to understand how this is achieved.

A glovebox is basically a closed volume. When the blower unit draws air (negative side) from the box, the box is under negative pressure. The filters help regulate this pressure. Filters are basically controlled leaks that allow airflow through them while trapping the particulates they are designed to filter out. The inlet filter establishes the actual glovebox working pressure, while the exhaust filter system establishes the inherent safety feature. It is therefore critical for the exhaust filter to be properly engineered into

the system to perform its inherent duty. When a glove port breach occurs, by design the inlet filter is bypassed and the breached glove port becomes the inlet.

The air change rate is an important consideration for all gloveboxes. As glovebox volume increases, airflow should increase. However, the inherent safety feature of 100 fpm through a glove port must be maintained. For normal operations, flow rate is based on the dilution of evolved combustible or corrosive gases and heat dissipation, and is often based on prior experience (see Sections 7.2.1 and 7.2.2). The exhaust capability must be sufficient to provide safety under postulated abnormal conditions, including the glove port breach.

Operating personnel, industrial hygienists, and radiation specialists can assist the designer in establishing realistic requirements, particularly when an existing system is being replaced or revised. The types and quantities of materials to be used inside the box and their toxicity and state (wet slurry, dry powder, etc.) must be considered when establishing the air exchange rate and velocity. When exposed radioactive material is handled inside a glovebox, the box becomes the primary containment. When handling nuclear and pyrophoric materials, consideration should be given to whether pressure inside the glovebox should be positive or negative. A positive-pressure glovebox provides a motive force for airborne contamination to leak from the box into the secondary containment (the facility). Negative pressure inside the box is essential to maintain glovebox containment when working with radioactive material. In an application where an inert environment is used to control fire and explosion, the box may be slightly positive or even neutral, and the facility becomes the primary containment. This suggests the need for a secondary containment and also flags the need for PPE and appropriate procedures to protect the worker. The designer must design for failure, i.e., using the worse case scenario, the designer must predict the consequences of a glovebox failure.

7.2.1 BLOWERS

The blower is the motive force which provides the pressure and airflow requirements in a glovebox. Although the related principles are covered in